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THE INFLUENCE OF AGE AND CONDITION OF THE TREE UPON SEED PRODUCTION IN WESTERN YELLOW PINE.

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THE INFLUENCE OF AGE AND CONDITION OF THE TREE UPON SEED PRODUCTION IN WESTERN YELLOW PINE.

TESTS ON WESTERN YELLOW PINE SEED.

The influence of the character of the mother plant upon the quality and quantity of seed produced and upon the character of the offspring is a factor which is well recognized in plant breeding. In forestry this factor should be considered not only in collecting seed for artificial propagation, but also in the selection of trees to provide for the natural regeneration of cut-over areas. In selecting seed trees the forester must ask himself: "Which trees will produce the best quality and the greatest quantity of seed?" and finally, "Which will produce the most desirable seedlings?" Secondary, though very important, considerations which should govern the forester in his selection of trees to provide for the future stand after cutting are wind firmness and merchantable deterioration or appreciation.

This circular deals primarily with the conditions affecting the germinative quality of the seed. The influence upon the quantity of seed, though of great importance, will be treated only as a secondary topic, because the data on this phase of the subject are incomplete.

The species studied was western yellow pine (*Pinus ponderosa*). The locality was near Maine, Ariz., on the Tusayan National Forest, elevation about 7,200 feet. In November, 1909, 100 samples, each consisting of from about one-tenth to 1 bushel of cones, according to the amount available, were collected from 100 trees representing different ages, sizes, and conditions of soundness and general health. The cones were collected in connection with a logging operation, which made it possible to determine accurately the age and soundness of the tree. In the case of young trees which were not felled the age and soundness had to be estimated; but since the number of such trees was small and nearly all of them were thrifty, the errors in these estimates will not be great enough materially to affect the results. In each case the sample was made up of cones from all parts of the crown. Careful data were taken on each sample, according to the outline on page 4.[1]

[1] The seed samples and accompanying data were gathered by Forest Assistant Harold H. Greenamyre.

Tree No ....
Height (feet) ....
Diameter breasthigh (inches) ....
Age (years) ....
Clear length ....
Condition of bole ....
Condition of crown ....
Fire scar? ....
Spike top? ....
Other peculiarities ....

Yield of cones (bushels) ....
Condition of cones ....
Number of cones in sample ....
Dry weight sample (pounds) ....
Weight seed (ounces) ....
Site:
Exposure and slope ....
Soil ....
Ground cover ....
Stand ....

TABLE 1.—*Comparative germination of seed of western yellow pine—Coconino Experiment Station.*

Tree class.	Duration of test (days). Average germination (per cent). 15	20	25	30	40	50	Basis.	Average yield of cones per tree.	Basis.	Average amount of seed per pound of dry cones.	Basis.	Average number of seed per pound.	Basis.
							Trees.	*Bush.*	*Trees.*	*Ounces.*	*Trees.*		*Trees.*
Yellow pine	42	58	61	64	67	68	60	1.8	55	1.3	47	12,065	62
Blackjack	52	69	72	74	75	76	38	1.0	8	1.7	36	12,624	38
Healthy yellow pine	41	55	57	61	63	64	28	1.8	27	1.2	20	11,362	28
Healthy blackjack	53	71	74	76	77	78	34	1.0	8	1.5	13	12,305	34
Unhealthy yellow pine	43	58	65	69	70	71	34	1.7	30	1.4	27	12,644	34
Unhealthy blackjack	44	55	57	59	60	61	4	......	......	1.9	2	15,352	4
Open stand[1]	46	62	65	68	70	70	73	1.8	51	1.4	59	12,223	73
Medium stand[1]	41	57	61	65	68	69	18	1.1	13	1.5	16	12,498	18
Dense stand[1]	56	77	78	79	79	79	9	.7	4	1.8	8	12,294	9
By decades:[1]													
140	63	78	80	82	83	84	4	1.2	3	1.5	3	......	......
150	68	84	86	87	87	87	2	1.1	2	1.0	1	......	......
160	55	68	70	71	73	73	7	.8	6	1.5	5	......	......
170	53	68	70	72	74	74	6	1.5	6	1.3	6	......	......
180	36	50	54	58	61	62	11	1.7	10	1.4	7	......	......
190	48	63	69	75	77	77	4	1.7	4	1.2	3	......	......
200	35	74	81	82	82	82	1	4.0	1	......	......	......	......
210	33	55	58	61	64	66	8	2.1	8	1.3	5	......	......
220	29	42	45	47	49	50	5	1.0	5	1.2	5	......	......
230	56	77	78	82	83	84	2	1.5	1	1.0	1	......	......
240	48	56	61	66	72	74	2	2.3	2	.9	2	......	......
250	54	86	86	88	88	88	1	1.5	1	2.0	1	......	......
260	....	....	....	....	....	....	......	......	......	......	......	......	......
270	....	....	....	....	....	....	......	......	......	......	......	......	......
280	20	24	26	33	38	39	2	2.1	2	1.2	2	......	......
290	43	52	57	60	61	61	2	.6	2	1.5	2	......	......
300	....	....	....	....	....	....	......	......	......	......	......	......	......
310	36	53	57	62	63	63	1	.3	1	......	......	......	......
320	3	7	8	14	22	36	1	2.0	1	1.3	1	......	......
330	38	79	80	81	83	83	1	2.0	1	.9	1	......	......
340	26	50	55	62	70	71	3	1.3	2	1.4	2	......	......
350	70	80	82	83	83	83	2	3.3	2	2.0	1	......	......
360	....	....	....	....	....	....	......	......	......	......	......	......	......
370	....	....	....	....	....	....	......	......	......	......	......	......	......
380	12	15	16	18	24	27	1	2.5	1	1.2	1	......	......
390	61	70	72	74	75	75	2	3.0	2	1.2	2	......	......
400	43	76	77	78	78	78	1	2.0	1	.9	1	......	......
Below 140 (diameter breast-high 14 inches and below)[2]	52	71	73	77	78	81	20	......	......	......	......	13,256	21
140-250[1]	45	61	65	69	70	71	[3]64	1.6	49	1.3	39	11,652	63
260-400[1]	37	52	54	58	62	63	16	2.0	15	1.3	13	13,447	16

[1] All trees.
[2] Blackjack, not cut. Age estimated.
[3] Includes 10 "blackjack" 15-22 inches diameter breast-high and 1 "yellow pine" 17 inches diameter breast-high whose exact age was not determined.

Table 1 gives a comparison of the different classes of trees with reference to germination and yield.

The cones were air dried. Each sample was placed in a 2-bushel sack immediately after collecting and kept there through the entire process of drying. The amount placed in each sack was in no case more than 1 bushel, though by the time the cones were fully opened the volume had about doubled. The drying process, which involved daily turning of the sacks, required about six weeks. No rain or snow fell in the meantime. The seeds were extracted by first shaking the cones violently in an iron tub and then striking each cone separately against the side of the tub. They were cleaned by rubbing between the hands, and later allowing the wings to blow out by pouring the mass slowly from one vessel to another in a light breeze, care being exercised to prevent the light, hollow seed shells from blowing out, because obviously these should be considered in the germination tests.

The germination tests [1] were made at Washington by planting 200 seeds from each sample in a sand flat and subjecting them to a hot-house temperature of 60° F. The duration of the test was 52 days, during which period counts were made every two or three days.

The terms "blackjack" and "yellow pine" will be used in this circular to distinguish two forms of the species *Pinus ponderosa*. "Blackjack" is the local name applied to young, vigorous trees characterized by a dark, almost black bark. "Yellow pine" is the local name applied to the older trees characterized by a yellowish or reddish brown bark. Lumbermen generally regard the two forms as distinct species, but the only difference is that due to age.

From Table 1 the following deductions may be made:

GERMINATION.

Seed from young trees shows a higher germination than seed from old, mature, or overmature trees. The 38 blackjacks used in this test give a germination of 76 per cent, against 68 per cent for the 60 yellow pines. A comparison of 20 trees near Cliffs on this Forest in 1908 gave a germination of 68 per cent for yellow pine, against 80 per cent for blackjack. Classifying both blackjack and yellow pine according to age, by decades, the germination per cent is found to fall with the increase in years. This decline is, however, by no means regular. For instance, 5 trees 220 years old show an average germination of only 50 per cent, while 2 trees 390 years old show an average of 75 per cent. Dividing all trees, both yellow pine and blackjack, into three age classes, namely, below 140 years (8 to 14 inches diameter breast-high), 140 to 250 years, and 260 to 400 years, the average germination per cents are found to be 81, 71, and 63, respectively.

[1] Conducted by Mr. N. H. Grubb, Office of Silvics.

Certain injuries decrease while others increase seed quality. A comparison of healthy and unhealthy trees shows the following germination per cents: Healthy yellow pine, 64; unhealthy yellow pine, 71; healthy blackjack, 78; unhealthy blackjack, 61. In classifying the trees with respect to health, those affected by heart rot, insects, mistletoe, dying top, fire scars, and suppression are classed as "unhealthy," while those showing no indications of disease or injury are classed as "healthy." These terms mean but little, however, unless we inquire into the actual condition of the tree. Grouping the 34 trees classed as unhealthy according to the nature of the injury, the following interesting comparison is derived:

TABLE 2.—*Comparative quality of seed from healthy and unhealthy trees.*

	Healthy.		Unhealthy.				
	Yellow pine.	Black-jack.	Heart rot, yellow pine.	Spike top, yellow pine.	Fire scar, yellow pine.	Bark beetle, yellow pine.	Mistletoe, black-jack.
Germination.........per cent..	64	78	67	79	79	37	51
Basis.....................trees..	28	34	10	7	15	3	3

Yellow pine affected by heart rot shows a germination 3 per cent higher than that of sound, healthy yellow pine. This difference, based upon only 10 trees, is hardly sufficient to establish the conclusion that heart rot increases germinative quality, but at the same time tends to show that at least the seed of such trees is not inferior to that of sound trees. The smallness of the effect is probably due to the fact that the rot works upon the heartwood exclusively and does not directly attack the vegetative life of the tree. If the rot should become sufficiently advanced to reduce materially the vitality of the tree, it is probable that the quality of the seed would be impaired and the quantity diminished. On the other hand, the fungus in its earlier stages may act as a stimulus, as in the case of "spike top" and fire scars, considered in the paragraphs following.

Spike tops show a germination 15 per cent higher than that of the healthy yellow pine. "Spike top" is the common term applied to trees with dead leaders, generally caused by some mechanical injury, most frequently lightning. The wound is usually followed by a fungous attack. The leader dies back from year to year, and as the upper branches drop away a straight shaft is left projecting above the living portion of the crown. The injuries causing spike top evidently act as a stimulus upon seed production. This peculiarity—apparently nature's provision for the perpetuation of the species—although not fully understood, is a matter of common observation.

It is in accordance with the same natural law which governs sprout growth after a basal burn, and the production of adventitious shoots after an injury on the stems or branches of certain broadleaf trees.

Yellow pine marked by fire scars shows a germination 15 per cent above that of healthy yellow pine. Fire scars are confined almost entirely to the base of the tree. They begin as a small burn in the bark and cambium, but increase in size and depth with recurring fires, until finally they sometimes extend 5 feet or more up, and one-half or two-thirds through the stem. Trees thus affected generally bear no marked signs of reduced vitality except in advanced stages, although possibly measurements might show a diminution in growth. The direct effects of the burn are a reduction of the water supply of the crown of the tree because of the destruction of more or less of the water-transporting elements, and at the same time a reduction of the food supply of the roots through the destruction of some of the elements bringing elaborated food material from the crown to the roots. It is evident that the food supply of the roots will suffer more than the water supply of the crown, because the elements bringing down the food, being nearer the surface, are more readily destroyed by the fire. The eventual result will be a reduction of the food supply of the entire tree, due to a reduction of the amount of water which the tree is able to absorb. In spite of this fact, burns appear to stimulate seed production, as does the injury causing spike top.

Mistletoe-infected blackjack shows a germination 17 per cent below that of unaffected blackjack. Although mistletoe stimulates growth in the immediate region of the parasite, causing the abnormal development of certain branches, the excess of carbohydrates produced by the additional foliage of the mistletoe-stimulated branches is used by the parasite itself, so that the final result is a drain upon the tree. It seems highly improbable that mistletoe would ever act as a stimulus upon seed production, because its action is insidious, slowly sapping the vitality of the tree instead of causing injuries in the nature of a shock, as is the case with burns or other mechanical injuries.

The effect of suppression is not clearly demonstrated. Of the two yellow pine included in our data, one has a germination per cent of 92 and the other only 14.5, the average of the two being 53, or 11 per cent below that of normal yellow pine. The only blackjack tested shows a germination of 90.5 per cent, or 12.5 above that of the average healthy blackjack. On account of the great variation between the individual trees cited above, it is impossible to predict the result of averaging a large number of trees. One would naturally expect to find an inferior quality of seed on a suppressed tree, but this would vary with the degree and period of suppression. It will also be counterbalanced to a certain extent by those factors which

tend to better the quality of seed in dense stands, such as more favorable conditions for pollination and the moderating effect of close crown cover, described in the following paragraph:

The highest quality of seed is produced in dense stands. The germination for open, medium, and dense stands is 70 per cent, 69 per cent, and 79 per cent, respectively. The difference between the open and medium stands is too small to establish any conclusion one way or the other; but the difference in favor of the dense stand is very pronounced. At first thought one might expect to find the highest quality of seed in open stands where light conditions are most favorable. There are, however, a number of factors which tend to explain why the contrary is true. First, it is obvious that the denser stands afford the best conditions for pollination; secondly, the moderating effect of a close crown cover upon temperature and evaporation would favor seed development, especially in the early stages. Many young cones die during the winter and spring, probably as the result of the unseasonable freezes and the drying winds which are very prevalent. Flowers suffer in the same way. Instrumental observations at the Fort Valley station show that the minimum temperatures under a fairly close canopy are commonly from 3° to 17° higher, and the wind movement and evaporation from 50 to 100 per cent less than in the open.

That the age and condition of the tree apparently have no material effect upon the rate of germination is evinced by the fact that the ratio between the germination per cents of different tree classes remains practically constant throughout the period of the test.

YIELD.

No accurate data with regard to the absolute yield in seed are available, but a rough measure of this yield is expressed by the production of cones given in the preceding table. It should be remembered that, in comparing yields with a view to determining the influence of the character of the tree, it is necessary to consider, in addition to the condition of soundness and general health, also the crown development of each tree, a feature which is determined largely by the density of the stand. Moreover, it is to be taken for granted that, other things being equal, the yield will increase with age until a certain age limit is reached. An exact study of the factors influencing both germination and yield is much more complicated than one in which germination alone is considered. Since this study was undertaken with the primary object of determining the conditions affecting germination, the data on yield are incomplete; nevertheless it is worth while to make a few comparisons based upon the data available, making due allowance for the evident inaccuracies in the results.

A comparison of yellow pine and blackjack shows an average yield of 1.8 bushels of cones per tree for the former and 1 bushel for the latter. This difference is attributable mainly to a difference in the size of the trees, the yellow pines on account of their greater age being on the average much larger than the blackjacks. A comparison of the classes with respect to the amount of seed produced by a pound of dry cones gives 1.3 ounces for the yellow pine against 1.7 ounces for the blackjack. It therefore appears that, although the younger trees yield less cones, when the amount of seed produced by a given quantity of cones and the vitality of the seed are considered, these trees are better seed producers for their size than the older trees. In comparing the two age groups from 140 to 250 years and from 260 to 400 years we find, as in the case of the blackjack and yellow pine, a considerably greater yield of cones for the older trees. The amount of seed produced by a pound of cones is, however, the same for both groups. The difference of cone production is much less pronounced between these two age groups than between the blackjack and yellow pine, because many of the trees included in the lower-age class have passed beyond the blackjack stage. Practically no data are available on trees below 140 years, since the trees were not felled, and only a small number of cones were picked from each tree.

A comparison of the healthy and unhealthy yellow pine shows only a slight difference in cone production. There appears a pronounced difference between the healthy and unhealthy blackjack, but, since we have accurate data for only two unhealthy blackjacks, this comparison is not conclusive. Furthermore, as in the case of germination; a comparison of healthy and unhealthy trees is of little significance unless we consider the nature of the injury in the unhealthy trees.

A comparison of the trees classed as unhealthy, considering the nature of the disease or injury, is shown in Table 3.

TABLE 3.—*Comparative yield of cones from healthy and unhealthy trees.*

	Healthy.		Unhealthy.				
	Yellow pine.	Black-jack.	Spike top, yellow pine.	Fire scar, yellow pine.	Heart rot, yellow pine.	Bark beetle, yellow pine.	Suppressed, 4 yellow pine, 1 black-jack.
Yield of cones per tree..bushels..	1.8	1	0.9	2.1	2.1	1.1	0.4
Basis..................trees..	27	14	6	15	10	3	4

Although the yellow pines affected by heart rot show a yield of 0.3 bushel more than the healthy trees of this class, the difference is probably due mainly to the fact that the trees affected by heart rot

are usually old and consequently of large size. The average diameter of the healthy yellow pine in this study is only 23 inches, against 27 inches for those affected by heart rot. It is probable that, as in the case of germination, the rot ordinarily has no material effect.

Spike tops show a yield only one-half as great as that given for healthy yellow pines. This is probably due to a reduction in the size of the living crown. The living branches of spike tops are frequently heavily laden with cones, and it is probable that the injury causing the death of the top acts as a stimulus upon cone production, as upon the vitality of the seeds.

The influence of basal burns upon yield is not fully demonstrated. The yellow pine bearing fire scars shows an average yield of 0.3 bushel more than the healthy yellow pine; but a comparison of diameters shows that the scarred trees have an average diameter of 25 inches against 23 inches for the healthy ones. Whether the greater yield is due entirely to the greater size of the burned trees or whether the influence of the burns is also a factor, can not be determined from the data at hand.

The yield of trees suffering from suppression and attacks of bark beetle and mistletoe are all much below that of normal trees of their class. While the number of trees in each case is too small to furnish reliable data, the results are very significant.

The yield decreases as the density of the stand increases. The average yield of cones per tree for open, medium, and dense stands are 1.8, 1.1, and 0.7 bushels, respectively. This difference is undoubtedly due mainly to a difference in crown development as influenced by growing space. Since western yellow pine is very light demanding, the trees growing in close stands have narrow, short crowns, and only those branches which are exposed to full or nearly full sunlight bear any cones whatever. Therefore, although the seed produced by a tree in a close stand is of higher quality than that produced in the open, as indicated by the germination tests, the total seed-producing capacity of a tree in a close stand is much lower.

APPLICATION OF CONCLUSIONS.

Blackjacks are the most desirable trees to leave for regeneration in cutting. The blackjack has the advantage over the older yellow pine in point of seed quality, and also in the rate of growth. A blackjack left for a future cutting will increase rapidly in volume, while a yellow pine will increase but slowly or even deteriorate.

In marking for cutting in the yellow-pine type it is the invariable practice to leave all healthy blackjacks, and also to leave a sufficient number of yellow pines to insure a second cut in about 30 to 50 years. But if a second cut were the only consideration in marking there would not always be sufficient provision made for seed

trees; because the trees left for a second cut do not have to be very evenly distributed over the area. Thus, one quarter section may contain an abundance of blackjack and yellow pine suitable to leave for a second cut, whereas an adjoining quarter section may contain mostly yellow pine which can be cut now, and very few seed-bearing blackjacks. Trees below 16 inches in diameter breast-high usually bear only small quantities of seed, and hence will not figure materially in the seed crop for the next few years. Therefore, if immediate reproduction is desired, wherever there are not enough seed-bearing blackjacks the deficiency must be made up from the youngest and best developed yellow pines available, even though not needed for a second cut. The number of trees per acre needed for seed purposes varies greatly with size and condition; on the average, from 3 to 5 yellow pines and about twice as many blackjacks (over 16 inches diameter breast-high) are required.

Spike tops and burned or decayed trees should always be cut, unless greatly needed for seed purposes. While such trees usually have a high seed-bearing capacity, to leave them standing until a second cut can be made involves merchantable deterioration or total loss. The risk in the case of light burns is comparatively small, but in the case of spike top and decay loss is certain. Since in extreme cases, however, it becomes necessary to leave defective trees for want of anything better, it is well to know that, unless too far gone, such trees can be expected to produce large quantities of superior seed for a number of years.[1]

Trees infested by mistletoe or bark beetles, even though not killed, are of little value for seed, and should be cut as being a menace to the forest. (Instructions in regard to the proper disposal of trees attacked by bark beetles are given in Bulletin 83, Part I, U. S. Department of Agriculture, Bureau of Entomology.) An exception to this rule may be permissible in the case of mistletoe, when the trees are isolated and when the attack is slight, but not in the case of bark-beetle infestation. Further investigations in regard to the effect of mistletoe and bark beetles are needed.

Isolated trees are preferable to those in close stands; first, because they usually have larger crowns; and second, because they are more windfirm.

For seed collecting, young trees are most desirable from a purely technical standpoint on account of the high vitality of their seed; but in practice, older trees are preferable on account of their heavier yield, and because the seed from such trees can often be collected cheaply in connection with logging operations. Such defects as spike top, burns, or heart rot are not objectionable; but trees affected by insects or mistletoe should be avoided.

[1] Records have been established to determine how long such trees will persist.